Neutrino Oscillation Parameters in a Six-channel Reduced Rank See-Saw

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Abstract. We demonstrate that it is possible to find parameters in a rank one see-saw model which give a reasonable representation of atmospheric neutrino data and of the LSND result. Solar neutrino data will require a complete description of the matter effect in the six channel space.

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INTRODUCTION

We have previously shown [1] that a rank one sterile mass matrix, in the context of the usual see-saw mechanism [2] may lead to very complicated neutrino oscillation patterns. In this contribution, we describe a selection of parameters that will give a description of atmospheric neutrino oscillations [3] and simultaneously provide an appearance signal for $\nu_\mu \to \nu_e$ consistent with the LSND [4] result.

The model assumes the existence of three Dirac mass eigenstates with closely spaced masses of the order of the heaviest of those neutrinos involved in existing experiments. Each of the three Dirac bi-spinors may be thought of as composed of a pair of Majorana spinors, one active under the $SU(2)_W$ and the other sterile. The see-saw mechanism is then implemented by assuming the existence of a large mass in the sterile sector.

In general, the sterile mass will be described by a full matrix in the three dimensional space spanned by the sterile spinors. This model makes the further assumption that this mass matrix is rank 1. That is, whatever mechanism produces the sterile mass picks out a single direction in the space. The parameters are then the magnitude M and the polar angles with respect to the axes defined by the Dirac mass eigenstates.

Diagonalizing this system produces six Majorana mass eigenstates. One Majorana neutrino mass is nearly totally active and has a very small mass (of order $\frac{m_D^2}{M}$) and one other has a mass of order M and is nearly totally sterile. The other four have masses of the order of the original Dirac masses and are strongly mixed.

CHOICE OF PARAMETERS

With this model, the evolution of a system prepared as a particular current eigenstate is calculated by mapping to the mass eigenstates, propagating them forward and then expressing the result in terms of the current eigenstates. In appropriate units, the prop-

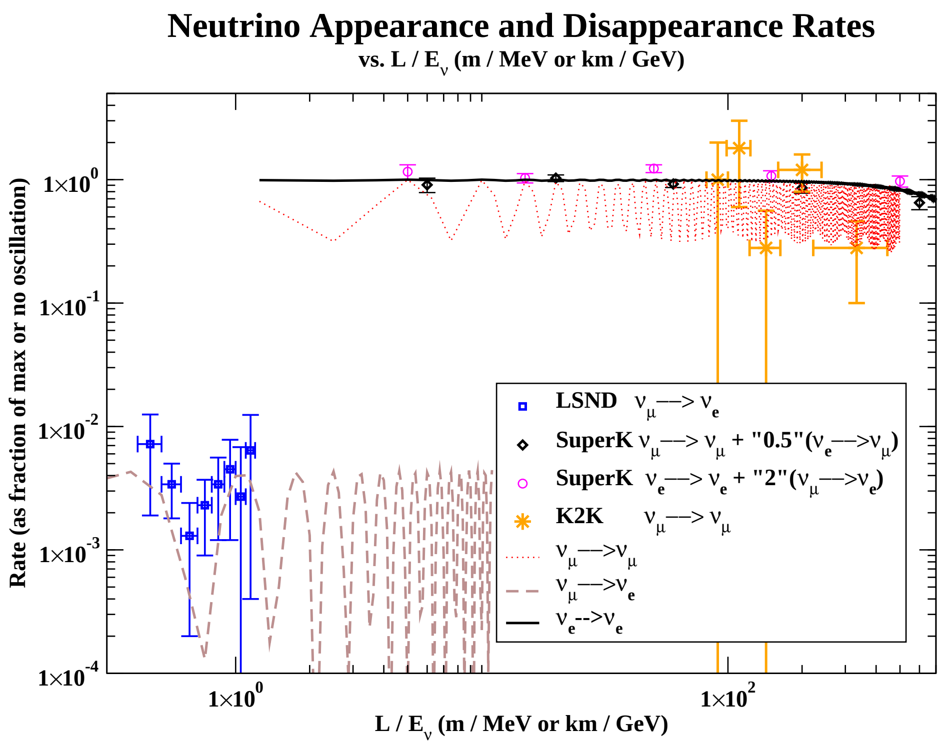

FIGURE 1. Appearance and disappearance probabilities

agation is given by $m_i^2 L/E$. The generalization of the PMNS [5] matrix to account for the six mass eigenstates is obtained by 3 by 3 mapping from the current eigenstates to the active components of the Dirac eigenstates before the 6 by 6 diagonalization. As this model is inspired by the possibility of quark-lepton symmetry, for this work we use the CKM [6] matrix for that mapping.

In order to suppress mixing into the sterile sector for small values of L/E, we found that we needed to select the polar angles so that the four similar masses actually formed two pseudo-Dirac pairs. Furthermore, to match the atmospheric neutrino data, we need to bring those two pairs into close proximity in mass. Meeting those two conditions, the $\nu_\mu \rightarrow \nu_e$ appearance probability would be extremely small without the CKM rotation. With that rotation, we find an appearance probability at the required L/E of a few times 10^{-3}.

Figure 1 shows the general form of results of such a calculation, treating all of the atmospheric effects as if there were only vacuum oscillations. This is clearly not correct for upward going neutrinos which have traversed the earth. The inclusion of the matter effect [7] in this model is complicated. Each mass eigenstate has components of all three active flavor eigenstates as well as sterile components. This means that there will not just be an effective mass change but that the system must be rediagonalized point by point as a function of the matter density and of the energy. The complexity required to treat the

MSW [8] effect in this way has led us to not address solar neutrinos in this paper.

CONCLUSIONS

This simple model, drawn from the idea of quark-lepton symmetry, is capable of producing rather complex vacuum oscillation phenomena and may well be able to accommodate the existing range of experimental data. To properly deal with data, the appropriate matter effects must be included and, eventually, additional PMNS rotations may have to be incorporated. Without matter effects, it is sufficient to have L/E distributions; matter effects will require an independent knowledge of E.

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